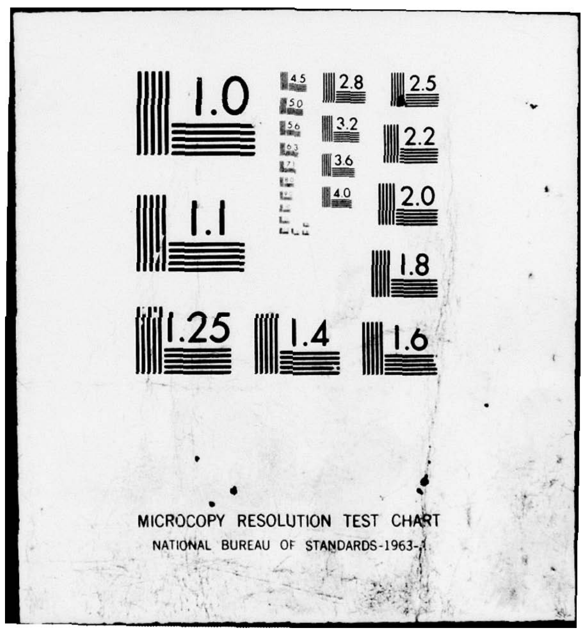
AD-A075 960 PUBLIC RESEARCH INST ALEXANDRIA VA F/G 11/6
THE PRICE DIFFERENTIAL BETWEEN DOMESTIC AND IMPORTED STEEL,(U)
OCT 77 J M JONDROW , D E CHASE , C L GAMBLE DL-J9-K600-05
UNCLASSIFIED CRC-311 NL

| OF |

AD
A075960

END
DATE
FILMED
11-79
DDC


1.0
4.5
5.0
5.6
6.3
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-

(14) CRC-311

(1) LEVEL II

02 031100.00

AD A075960

(6)

THE PRICE DIFFERENTIAL BETWEEN DOMESTIC AND IMPORTED STEEL

CENTER FOR NAVAL ANALYSES
1401 Wilson Boulevard
Arlington, Virginia 22209

(10)

By: James M. Jondrow, David E. Chase, Christopher L. Gamble

(11) Oct[redacted]77

(12) 42

(15) DL-J9-K600-05

PUBLIC RESEARCH INSTITUTE
a division of the Center for Naval Analyses

A048 6[illegible]2

THE PRICE DIFFERENTIAL BETWEEN DOMESTIC AND IMPORTED STEEL

The material in this research contribution was prepared under contract J9K60005 with the Bureau of International Labor Affairs, U.S. Department of Labor. Points of view or opinions stated in this document do not necessarily represent the official position or policy of the Department of Labor.

DL-J9-K60005

Prepared for:
The Bureau of International Labor Affairs
Department of Labor
Washington, D.C. 20210

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

It is often claimed that U.S. industry cannot compete with imports; that lower-priced imports will capture the whole market. This paper is about a counter-example. Imported steel has, for the last 15 years, often been priced well below domestic steel. Yet the majority of purchasers continue to choose domestic steel. We seek to explain why two prices can continue to exist for what is often considered a standard commodity; why the low-priced product does not drive the expensive one from the market.

From a literature search and interviews with those close to the steel market, we conclude that while the price of imports is generally lower than the price of domestic steel, (except during shortages) imports are unattractive to buyers for several reasons. Important drawbacks are these:

- During shortages, import prices rise and they cannot be ordered through usual channels,
- Import lead times, from order to delivery, are often long and uncertain,
- The required size of purchase for imports is large.

Because of these characteristics, import users must bear the extra costs of keeping large inventories. Product quality and credit conditions are not important negative qualities of imports.

Illustrative calculations are presented to indicate how two of the most important characteristics of imports can affect the costs of using steel for a typical purchaser: high prices during shortages and long lead times.

To compensate import users for high prices when steel is in short supply, they must be offered a discount when demand is slack. Our calculation of this discount takes account of the ability of steel users to conserve when the price of steel is high and also takes account of the tendency of imports to be high in price exactly when they are most desired, when demand for steel-using products is heavy. Our calculations are based on the strong assumptions that when demand for steel is heavy, one cannot switch from imported to domestic steel and that high import prices coincide with heavy U.S. demand.

Using these, and other, assumptions, we found that when demand is slack, imports must sell for 9 percent below the domestic price.

On average, users of imports must place orders three months in advance of delivery rather than the one-month lead time required of users of domestic steel. The estimated costs that import users must bear because of the longer lead times are sensitive to assumptions about how accurately steel users can forecast the demand for their product.

We assume that accuracy of prediction becomes proportionately less, the greater the distance in the future that must be predicted. This assumption is consistent with the accuracy of published forecasts for U.S. steel production, and is also consistent with the assumption that future demand is generated as a random walk. We find that the price of imports should be 9 percent lower than the price of domestic steel to offset the added inventory costs.

INTRODUCTION

In most years since the late 1950's, the price of imported steel has been below the domestic price. This low import price has been a recurrent worry to steel workers and producers, who fear that imports will force domestic mills out of business. Little help is expected from buyer loyalty to American steel: steel is steel and the buyer need only find the cheapest source.

The concerns of the steel producers and workers seem, at first, well founded in economic theory: two products which substitute perfectly in use simply cannot sell at different prices; either the higher price will fall to meet the competition or production of the higher priced one will stop.

But the production of domestic steel has not stopped, even though domestic producers have lost some ground to imports. Since the late 1950's, when imports first became low priced, the demand for imports has grown steadily and, sometimes, suddenly, as in 1968. Still, the amazing story is not that imports have grown swiftly, but that they have grown slowly. In 1962, imports had 6 percent of the U.S. market. In 1976, 14 years later, they had 14 percent. So each year, on the average, imports have increased their share of the market by less than one percent.

Why did imports grow so gradually? This is the central question of the paper. We explore two answers, one briefly, one in more detail. The first possible answer is that imports only seem to be lower in price, but actually are not. The second possible answer is that buyers do not consider imported steel to be a perfect substitute for domestic steel; that to them steel is not steel.

The first answer, that imports only seem to be lower in price, could be correct if published domestic prices are inaccurate. Domestic producers may discreetly charge less than the published price, in order to compete with imports. We examined the possibility that the observed difference is due to improper measurement and concluded that it is not. Import prices are, in fact, lower.

Given that imports are lower in price, it remains to be explained why the growth of imports has been so slow. It must be that imports are not the same product. From a review of the literature and interviews with buyers and sellers, we concluded that imported steel is not physically different from domestic steel, but that there were differences in the purchasing process itself. Imports must be ordered farther in advance of delivery and the import price fluctuates sharply. Because greater lead times and fluctuating prices impose costs on purchasers, foreign producers must offer lower prices to compete at all in the U.S. market.

The distinction buyers make between imports and domestic products is important for both policy and research. It helps explain why imports do not rush in; why their market share grows slowly. If the slowness were unexplained, it would be hard to feel confident that imports will not suddenly dominate the market. Policy is much simpler if the gains from trade do not come at the expense of sudden and massive costs to a few workers and producers.[1]

The distinction between imports and domestic products has implications, too, for economic research. It supports the assumption, common in empirical studies of import demand and recently incorporated in theoretical work, that imports do not substitute perfectly for domestic products. Empirical work that uses this assumption includes [2, 14, 17, 19, 20, 25, 27, 28]. Theoretical work that incorporates this assumption has been performed by Armington [1].

Our explanation of the imperfect substitutability between domestic and imported steel draws upon a review of the literature and interviews with steel buyers and sellers. Once we document that long delivery times and insecure supply price are problems to importers, we ask: are they really serious enough to account for reported differences in price? To answer this question, we estimate how much purchasers should be willing to pay to avoid these problems, how much the import price must be lowered to convince buyers to put up with the problems.

These estimates require strong, sometimes heroic assumptions. For example, we assume, throughout, that import purchasers expect that they will be unable to switch to domestic steel when demand is high and the import price rises. Switching to domestic steel must be done when there is some slack in the demand facing domestic sellers. Furthermore, we assume that the foreign demand moves in a cycle that matches the timing of the U.S. business cycle.

The number of purchasers who place a high value on the problems with imports will affect the demand for imports. The relation between the demand for imports and the value of the particular characteristics of imports is illustrated in figure 1. The demand curve is drawn under the assumption that the price of domestic steel is held constant. The downward slope comes from the different values placed on the characteristics of imports by different buyers.

---

[1] This is not to say that slow import growth makes free trade more desirable. In fact, the gain to consumers is largest when imports substitute closely for the domestic product and take over the market at once. Still, there is a reluctance to harm steel workers and producers, especially if the damage is sudden.

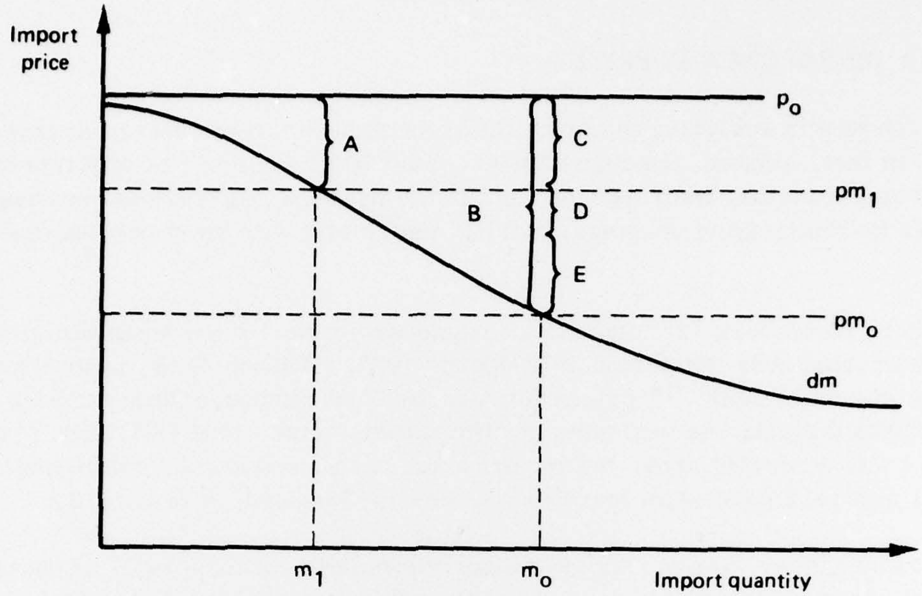


FIG. 1: THE DEMAND FOR IMPORTS HOLDING CONSTANT THE PRICE OF DOMESTIC STEEL

In figure 1, the curve dm represents the demand for imports, holding the price of domestic steel constant at p_o. If the price differential in favor of imports is modest, say A, then the quantity of imports demanded is modest, m_1. A typical steel purchaser might require a differential as large as B before switching to imports.

Measurement of the value of waiting time, security of supply, and other factors, to a typical steel user involves disaggregating B into portions that correspond to the value of the individual characteristics, shown in the figure as C, D, and E.

DISCUSSION

IS THERE A DIFFERENCE IN PRICE?

The first step in analyzing the price differential should be to document that the differential has, in fact, existed. Documentation comes from a number of different sources including formal studies, informal accounts in the press, Congressional hearings, International Trade Commission hearings, and our interviews with steel purchasers and producers.

A study by Rosenberg [29] indicates that imported steel from Japan was priced lower than domestic steel over the period 1970-March 1973. Data on "U.S. base price and extras" are compared with CIF prices for Japanese and European steel for four popular types of imported steel. As examples of differentials quoted, the 1970 U.S. price of hot rolled sheet was 4 percent above the import price, a relatively minor differential. The differential was 16.2 percent in March 1971, and 13.3 percent in mid-1972.

Kravis and Lipsey [18, p. 222] used interviews with purchasers to compare export prices for various countries for selected years between 1953 and 1964. Taking the U.S. export price as a representative of the internal price, domestic steel sold for about 30 percent more than Japanese steel in 1964.

Reports in the press also indicate that at times there has been a substantial difference between the prices of domestic and imported steel. For example, a report in the Wall Street Journal [5] in late 1975 states that "the era of cheap foreign steel has gone the way of cheap foreign oil." An article in the 1968 Wall Street Journal [36] describes the beginning of a price war among major steel companies precipitated by price shading meant to bring domestic prices closer to lower foreign prices.

A 1967 staff study on Steel Imports [3, pp. 365-413] for the Senate Committee on Finance reported the results of a survey of domestic steel producers. They were asked to provide detailed information on the delivered prices for domestic and imported steel of fairly detailed specifications. For hot- and cold-rolled carbon sheets, where the most responses were received, the reported differential ranged from 4 percent to 35 percent. As an example, one price comparison in Michigan showed domestic hot-rolled sheets delivered at $149 per ton and imported at $107, a 28 percent differential.

The 1968 Congressional hearings [11] include reports of delivered prices for imported and domestic steel for the period 1965-1968. These were provided by a major importer. The source may be important since he presumably had incentives different from the steel producers who reported price for the 1967 Steel Import Study. Indeed, the quoted differentials tend to be at the low end of the range quoted by U.S. producers. Yet, the prices he quoted also show that foreign steel sold for less. For example, in the period 1965 to 1968, imported hot-rolled coils sold at between 7.6 percent and 22.3 percent less than domestic costs.

The percentage differential has apparently been especially large in stainless and tool steels. For example, a study by the International Trade Commission [35] reported differentials for stainless steel plate ranging from 0 to 30 percent for the years 1971 to 1975.

CHARACTERISTICS OF STEEL TRANSACTIONS AND THEIR IMPORTANCE TO PURCHASERS

Imported and domestic steel, and, indeed, domestic steel from different sources (major mills, mini mills, warehouses, and brokers) can be distinguished by attributes other than price. Important ones are:

- quality of products
- delivery lead time
- certainty of delivery lead time
- credit conditions
- required size of purchase
- availability and cost of non-base extras
- familiarity with domestic product
- relative transactions cost
- security of supply*

The existing literature relies on some of these characteristics to explain why imports must be priced lower if they are to sell.

Literature Survey

Kravis and Lipsey [18, pp. 158-163] cite evidence that for metals and metal products, the ability to offer quick delivery is an important competitive advantage. One large aluminum consumer switched from foreign to domestic supply"...despite his ability to obtain European aluminum at a saving of 5 to 10 percent in the delivered price, owing to the costs of maintaining adequate margins of safety in his stocks" [18].

Hogan [13, p. 2037], in history of the steel industry, cites as disadvantages of imported steel in the mid 1960s:

"1. The lead time for placing orders was substantially longer than required by American Mills...

*Security of supply as used here means that the consumer is assured of a particular price in the future, and that he can obtain his normal supply.

"2. In a number of instances, it was necessary to buy very large quantities of steel.

"3. The actual cost of unloading from port, transportation to point of use, and unwrapping was considerable. For some products, it was placed at $4 to $5 per ton." (At the time, this was about a 3% differential on hot-rolled carbon steel sheets.)

He notes that the import price had to be well below the American price for the above reasons and because many Americans were skeptical of import quality.

According to Miller [22, p. 18], purchasers regard the availability of foreign steel as "at best, a cyclical phenomenon." Miller also claims that industries using large quantities of steel, such as autos, appliances, and containers, continually negotiate price with suppliers so that list prices may not be a good measure of actual prices paid. The inaccuracy of list prices should not be accepted too readily. Stigler and Kindahl, in a major study on prices reported by purchasers [33], found that list prices for steel are accurate.

Miller also states that imports cannot match the continuity of supply provided by domestic sources:

> "Day to day continuity of supply is of such paramount importance that price differences typically existing between imports and domestic steel producers simply would not compensate purchasing firms for the additional risks inherent in foreign supply."

Miller's concept of continuity of supply seems to combine short lead time and security of supply. It is interesting that the riskiness of import supply was noted as early as 1968 when the Miller paper was published. This indicates that fears of high prices and shortages of imports did not begin with the 1973-74 shortage.

In 1968, an importer testified before Congress [11] that imports must sell below domestic products because of slower delivery, problems of communication, transport hazards, and the necessity for users to carry large inventories to compensate for inflexible delivery schedules.

In these same hearings [12] a representative of an American wire company using imported wire rod, commenting on the quality of steel from different sources, said that American firms ranked no better and often worse than import suppliers. This conflicts with the suspicion about import quality noted by Hogan [13].

To summarize, these sources emphasized the disadvantage of the long lead time for imports. Also mentioned were insecurity of foreign supply and transactions costs. Conflicting reports were presented on perceptions of product quality.

Results of Interviews

To generate further information on the importance of various characteristics distinguishing domestic and imported steel, we conducted a number of interviews with representatives of firms dealing in the steel market, representatives of trade associations, and government officials.

The different types of firms or organizations interviewed are described in table 1.

TABLE 1

FIRMS OR ORGANIZATIONS INTERVIEWED

Type of firm	Number of interviews
Fabricators and wholesalers (purchasers)	10
Warehouses (purchasers)	5
Manufacturers of steel-using items (purchasers)	4
Domestic mills (sellers)	4
Foreign mills (sellers)	2
Trade associations	2
Government officials	1
	28

The scope of the interviews ranged from general discussions of how transactions proceed at various levels of the market, to specific questions about the relative importance of characteristics such as product quality and security of supply. We also asked about details of steel-using operations, especially inventory policy and behavior during the 1973-1974 shortage.

The interviews did not have a rigid format. Thus, we did not obtain responses about every factor from each interview. We tried to concentrate each interview on the factors the interviewee felt were most important in distinguishing imports from domestic production.

Table 2 summarizes responses, showing the number responding that a given characteristic was a competitive advantage for imports, relative to domestic steel. As can be seen from the table, imports have two important selling points, price and quality. Their important negative characteristics are insecurity of supply, long and uncertain lead times, and large purchase size required. The latter two are reflected in added inventory requirements. Credit conditions and transactions costs were not perceived as important.

TABLE 2

INTERVIEW RESPONSES TO QUESTIONS ABOUT FACTORS INFLUENCING CHOICE BETWEEN IMPORTS AND DOMESTIC STEEL

	Number responding					
Characteristics of imports	Most important positive	Positive for imports	Negative for imports	Most important negative	Not important	Not asked
1. Security of supply		2	4	8	2	12
2. Delivery lead time			15	1	1	11
3. Certainty of lead time			15		1	12
4. Required size of purchase			10		4	10
5. Inventory requirements			10		3	15
6. "Buy America" clauses			8		3	17
7. Availability and cost of non-base extras			7		4	17
8. Familiarity with domestic products			3		7	18
9. Relative transactions cost			3		11	14
10. Credit conditions		2	3		9	14
11. Quality		8	3	1	7	9
12. Price	15	1			1	11

A more detailed summary of responses is presented below.

Price: Our interviews reinforced the impression that, except for the shortage period, the price of imports has generally been lower than the price of domestic steel. One respondent said, "In most instances, foreign steel has to be sold at lower than domestic prices, or there is no reason for the purchase." Indeed, our table suggests that price is the most important competitive advantage of imports.

Quality: Most respondents defined product quality in terms of the fraction of material received that was unusable because of defects, such as cracking, and blemishes. This was described as an important characteristic in distinguishing between domestic sources of supply, but less important in distinguishing between domestic and foreign sources. Although import quality was considered questionable in the early 1960s, the situation has changed and many now feel that the quality of imports exceeds that of domestic steel.

Several users speculated that the reason for the higher import quality was that reshipping was more expensive for foreign exporters, and hence extra quality controls were used. A second speculation was that it resulted from their newer production equipment.

Delivery Lead Time and Certainty of Lead Time: A number of interviews indicated that foreign lead times were longer and less reliable. Average lead times were estimated as three months for imports and one month for domestic. One importer stated that three months' worth of orders had been delivered simultaneously, due to the unpredictability of import lead time.

Some large buyers of domestic steel are able to force lead time down even below one month by providing the mill with advance commitments for the coming year. What distinguishes this from simply ordering in advance is that the commitments need not be specific in their timing.

Credit Conditions: Credit conditions were considered unimportant or the same for both imports and domestic steel. One purchaser pointed out that credit conditions generally depend much more on the characteristics of the borrower than the lender.

Domestic sales almost always require payment within thirty days after delivery. A discount of 1/2 percent is provided if payment is made within 10 or 15 days. Import credit conditions are more variable, but one Japanese supplier claimed that credit conditions were actually superior for imported steel, with no payment until 3 months after delivery. However, a respondent who bought European steel during the 1960s said that payment was required upon delivery to the dock.

Required Size of Purchase: For steel from domestic mills, there are extra charges for quantities less than some base amount. The base quantities vary: 300 tons for rebars, 2 tons for structural shapes, 10 tons for plates. Foreign mills have minimum order sizes in the hundreds of tons.

Relative Transactions Cost: Transaction costs were generally not considered important. Those respondents that mentioned transaction costs for imports complained that there is no well defined policy on reshipment of defective orders, or that delivery is not always direct to your door.

Security of Supply: This was considered the most important disadvantage of imports due to experiences during the 1973-74 shortage. During this period, imports sold at prices well above domestic, and were not available in unlimited quantities from the usual sources. Several respondents reported that they would be unwilling to buy imports again because of this.

Buy America Clauses: These appear not only in federal law, but also in some state and local statutes. In some areas, such as Washington, D.C., there is so much government contracting that warehouses tend not to stock imported steel at all. Nationally, about 20 percent to 30 percent of construction is government contracted.* This excludes a sizeable portion of the market from imports.

Inventory Requirements: Users of imports will tend to hold higher inventories because of several characteristics: long lead time, uncertain lead time, and large required order size. A later section of this paper presents estimates of the inventory costs associated with longer lead time.

Summary of Interviews: The interviews suggest that price is the important competitive advantage of imports, reaffirming that there is, in fact, a differential between imported and domestic steel to explain. The major competitive disadvantages of imports were longer lead time, uncertainty of lead time, and insecurity of supply. (We feel that the higher inventory requirements for imports is simply a reflection of the longer and more variable lead time.)

In the following sections we analyze two of the competitive disadvantages of imports: supply insecurity and long lead times. Our purpose is to provide crude estimates of the cost that purchasers might plausibly impute to these disadvantages. These estimates often require strong assumptions, and hence will be of interest primarily for their order of magnitude.

---

*In 1976, new construction put in place was valued at $144 billion by the Department of Commerce. Of this, $36 billion was public.

THE COSTS OF INSECURITY OF IMPORT SUPPLY

A major selling point for domestic steel is the insecurity of import supply. The term supply insecurity describes a situation in which import prices rise sharply and other sources of supply will not accept new customers. The steel shortage of 1973-1974 provides a dramatic example of the problems purchasers of imports can face during a tight market.

The Steel Shortage of 1973-1974

A Description of the Shortage

The 1973-74 shortage was worldwide. Difficulty in obtaining imports and domestic steel were reported in the trade press at almost exactly the same time, April-May 1973. These reports trace the tightness in import supply to very strong demand in foreign markets [31, 6]. During May a series of articles appeared in the American Metal Market, speculating on whether there would be allocations [6]. By May 14, waiting times for domestic mills were up to 2 or 2-1/2 months for hot-rolled sheets from the normal lead time of one month or less [32]. Waiting times for wire rod reached as much as six months and producers began allocating places on domestic order books. The price of steel in foreign markets had already increased above the U.S. price, but the Japanese were still selling in the U.S. at the U.S. mill price. This was interpreted as a short run constraint imposed by informal commitments. It was not expected to last [7].

At the time the import price surpassed the price from domestic mills, it was hoped that the import price might peak at about a ten percent premium [7]. As the shortage progressed, however, it became clear that the peak would far exceed ten percent. Table 3 shows price indexes for domestic and imported steel. The domestic price index is from the Bureau of Labor Statistics. The import price is based on European export prices reported in the Metal Bulletin. Both indexes are taken from the report Steel Prices issued by the Council on Wage and Price Stability [34].

To allow comparison of absolute price levels, we adjusted the indexes so they would be equal in May 1973, when the domestic and imported price were equal, and used the adjusted indexes to estimate the ratio of the import price to the domestic price. This ratio, presented in column 4, suggests that the European price was above the domestic price from about May 1973 until the end of 1974.

In May, and the following months of 1974, U.S. mills were allowed to raise their prices sharply. At the end of 1974 demand had turned around and the shortage seemed to be over.

TABLE 3

PRICE INDICES FOR IMPORTED AND DOMESTIC STEEL DURING THE 1973-1974 SHORTAGE

		European export price	BLS price index	Relative import (European) to domestic price
1973	1	74	99	.75
	2	87	99	.88
	3	92	99	.93
	4	97	99	.98
	5	100	100	1.00
	6	106	100	1.06
	7	117	100	1.17
	8	119	100	1.19
	9	129	100	1.29
	10	131	101	1.30
	11	128	101	1.27
	12	125	101	1.24
1974	1	141	103	1.37
	2	149	104	1.43
	3	159	109	1.46
	4	164	113	1.45
	5	174	121	1.44
	6	175	127	1.38
	7	174	136	1.28
	8	166	140	1.19
	9	166	143	1.16
	10	160	143	1.12
	11	147	142	1.04
	12	140	143	.98
1975	1	113	147	.77
	2	109	147	.74
	3		147	

How Import Users Fared During the Shortage. As can be seen from table 3, import users had to pay much more for their steel than did users of domestic steel. On the average, imports cost about 25 percent more between July 1973 and December 1974.

There were some limits on the availability of imports so that, even at higher prices, importers were not getting all the steel they wanted through their usual sources. One importer was reported by the press as stating that his firm was getting only 10 percent of its requirements. Another received only 30 percent [16]. One of the purchasers we interviewed stated that his firm received no steel from their usual Japanese sources despite a purported close association with the Japanese supplier. Indeed, a note in American Metal Market pointed out that the Japanese Ministry of International Trade and Industry had required steelmakers to allocate more of their steel to Japanese purchasers [23].

However, these tales of distress cannot be considered representative. Imports did continue to enter during the shortage period, at a reduced rate, but at well above 30 percent of their previous level. What seems to have been happening is that imports entered through brokers or through other than regular channels. There is no obvious reason for this spot market to be out of equilibrium, even in times of price control. It seems plausible that imports simply became the subject of a continuous auction, clearing at high prices.

How Users of Domestic Steel Fared During the Shortage. The price of domestic steel did not rise sharply. Domestic producers handled the shortage by allocating supplies in strict proportion to 1972 purchases [26]. Import users were not denied supplies because they were importers, but because they lacked the appropriate purchasing history. Others also lacked this history. For instance, one purchaser complained that during 1972 he had been running down inventories and, as a result, was allocated less than he needed during the shortage [26].

There is disagreement as to the severity of the shortage. Some mills claimed they could have sold twice what they were producing [37] but clearly this could not have been true for all of them. As a rough method of computing the extent of the domestic steel shortage, we can estimate the amount of steel that would have been consumed if supplies had been readily available. This is done by projecting growth in demand on the basis of May 1973 shipments, since these represent orders placed in April, the last month before the heavy shortage demand hit. The projection was made on the assumption that later domestic shipments would have been the same proportion of real GNP as were May shipments. Projected and actual shipments [30] are compared in table 4.

TABLE 4

ACTUAL AND PROJECTED SHIPMENTS FROM U.S. MILLS
IN MILLIONS OF TONS

Quarter	Projected shipments	Actual shipments
1973 III	30.26	27.03
1973 IV	30.44	28.01
1974 I	29.89	28.80
1974 II	29.77	29.04
1974 III	29.62	26.53
1974 V	28.94	25.16
	178.92	164.57

Was the Shortage "Typical"

The constancy of the domestic price is valuable to purchasers; it is as if the domestic industry is selling insurance against high prices in boom times. The price of the insurance is the higher price paid during slack periods and the return on the insurance is the lower price during booms. For this insurance to maintain its value, future shortages must be expected; the shortage of 1973-1974 must not have been purely a historical accident.

There is no doubt that the shortage was, in some ways, unique. After all, this was the period of price controls. Without these controls, the domestic price undoubtedly would have been higher and the shortage at least partially prevented. Still, there are a number of reasons to believe that steel shortages can occur again.

Obviously shortages can occur again if price controls are reintroduced and serve to prevent the price increases that would clear the market. The Federal government, at least since the Truman administration, has been hostile toward sharp rises in the price of steel, and while price controls may be fairly new for the economy as a whole, they are not unfamiliar in the steel industry. There is no reason to expect that the political climate will favor steel price increases during the next shortage.

While the price of steel is unresponsive to demand, it is strongly influenced by average production cost and by historical prices. We found in our earlier research on the steel industry [17] that the price of steel was not sensitive to variations in capacity utilization (a measure of demand relative to industry size), once average cost was taken into account. The period that was analyzed included four instances of very high capacity utilization: 1950, 1953, 1955, and 1973-1974. The much publicized steel price increase of 1974 was not necessarily a response to increases in demand. It did no more than catch up with cost increases that had not been passed on to consumers.

That there will be shortages in the future is considered quite likely by users of steel. Indeed, our interviews with purchasing agents, taken just after the shortage, indicated that they were seriously concerned about the future security of their supplies. One purchasing agent, interviewed in the Wall Street Journal, stated that sometimes "price... becomes secondary to harmony," a position that would only make sense if future shortages were a real possibility. He went on to say:

> "Such was the case, to a degree, last summer (1975), when Mr. Konrad twice turned down offers of steel at discounts at least as large as those he was getting last month. The offers came in June and July, and Walker was just returning to steel buying after having spent most of the year working down inventories it had piled up following last year's coal strike. One offer was from Sharon Steel Corp., a smaller producer, which promised hot- and cold-rolled sheet through the third quarter at $40 a ton below the going price. The other was from a European mill, which offered 1,500 tons of galvanized steel at about $67 a ton below domestic prices.
>
> " 'It was a tough decision to pass up a $40 savings,' Mr. Konrad says of the Sharon proposal. But had he accepted either of the offers, it would have been at the expense of his six major suppliers, which hadn't received many orders from Walker all year. Buying foreign tonnage would have particularly affronted domestic mills, and Mr. Konrad felt that it would have been shortsighted to damage long-standing relationships for a one-time saving.
>
> " 'I just recommended that we not be overawed by the moment,' he recalls, 'because in a tight market we'd lose that savings so fast you wouldn't believe it. By doing what we did - investing with our regular domestic mills - we won't have to sit down in the next tight market and reinvent the wheel.' " [15]

The $40 discount on sheet in this quotation is 18 percent of list price; the $67 discount on imported galvanized steel is 24 percent of list price.

An Estimate of the Value of Supply Security

Given that there are no guarantees against future shortages, how much value might a steel purchaser plausibly impute to the secure supply of domestic steel, that is, the ability to buy it at a stable price? The price of imported steel is much more variable than the price of domestic steel. When import prices are high, users of imports lose money relative to those who use domestic steel. When import prices are low, they make money.

A first approximation to the appropriate discount for imported steel in slack periods is the one which equates the average price of imports over the cycle to the average price of domestic steel over the cycle.* However, this omits several facts about the steel market.

First, when prices are particularly high, users switch from steel to other factors of production. Hence, their loss of profits is not so great as would first appear. Secondly, import prices tend to be high during boom times, when demand is strong for products that use steel and profit opportunities are greatest. Some adjustment must be made for the fact that imports are high prices at exactly the time when it is most wanted.

Because of these complexities, we do not just choose the discount for imports which makes the import and domestic price average the same over the business cycle. Instead, we calculate the discount which makes average profits the same.

Our estimate of the value of supply security depends on the assumption that import users will continue to buy imports even when the price is high. While this is a strong assumption, there are several facts that lend it support.

First, purchasers were worried about security of import supply. This worry would not make sense if they felt able to switch from imports to domestic production at will.

Second, during the recent shortage, purchasers who lacked a history of buying domestic steel could not acquire it.

Third, results of our earlier research [17] indicate that substitution between imported and domestic steel is much weaker in the short run (1 year) than in the long run. A plausible explanation is that there are important costs to switching which lead one to change only rarely.

A Schematic Representation of Our Method

Our method for estimating the discount is depicted in figure 2. Line D1 represents the demand for imports under boom conditions. Line D2 represents the demand for imports under slack conditions.

*The assumption here is that imports are not bought when cheap, then stored until they become expensive. As will be seen later, the cost of storing steel for several years would be prohibitive. Hence, storing will be limited to short periods.

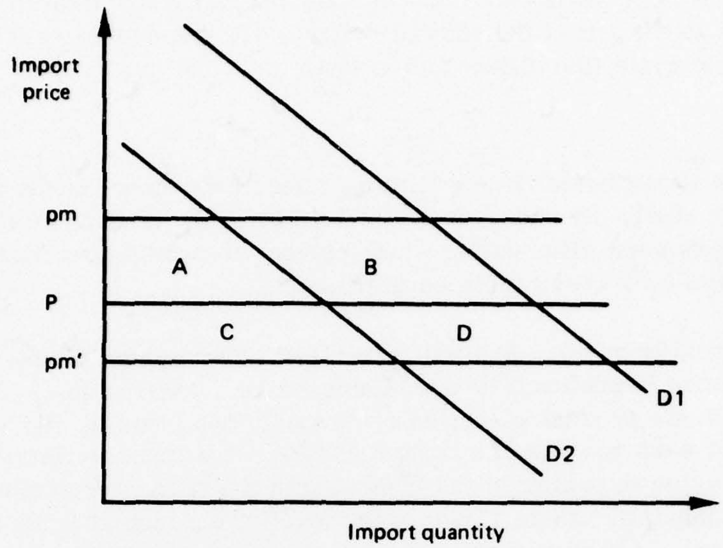


FIG. 2: THE DEMAND FOR IMPORTS UNDER SHORTAGE AND NON-SHORTAGE CONDITIONS

As mentioned above, the demand curves are drawn under the assumption that steel users do not switch back and forth between domestic and imported steel. Instead, they act as if they are bound to one source of supply by an implicit contract, negotiating new contract only rarely. Each demand curve represents the situation during a contract. Therefore, it does not show as much price responsiveness as it would if substitution were allowed between imported and domestic steel.

The demand curves are used to estimate the present differential in prices necessary to offset the possibility of high future import prices. We begin by depicting the losses to import users during a shortage. During a shortage, import price is pm . If the user has specialized in domestic steel, he would have been able to purchase domestic steel at price p . A consumer-surplus type measure of the lost profits of import users relative to domestic users is equal to area A+B.

To make up for this loss, the import purchaser will require some discount during non-shortage times (pm') . This discount will yield the purchaser a gain in profits measured by the area to the left of the non-shortage demand curve (D2) between prices p and pm' .

The appropriate non-shortage import price is the one that equates area A+B with area C , where each area is weighted by the frequency with which it is expected to occur.

To calculate the discount in the manner described above requires several types of information: the slopes of the demand curves (D1 and D2), the extent to which the non-shortage curve lies to the left of the shortage curve, and the degree to which the import price varies over the cycle (the difference between pm and pm').

The Model

The calculation is performed by simulating a quarterly model of the market for imported and domestic steel. By successive simulations of the model, we find the discount that foreign producers must offer during slack periods to provide purchasers with the same long-run profits as if they bought domestic steel.

The model is used to project domestic price and import price facing a typical steel user and the difference in profits if he used domestic or imported steel. Though the graphical analysis in the preceding section covers only two periods, the actual calculations are made for each quarter of a typical cycle. Once these projections are made, the discounted present value of profits at the beginning of the cycle is calculated for import users and users of domestic steel. The average level of the import price is adjusted until the discounted present value of profits is the same for users of domestic and imported steel.

The model includes six equations: one equation expressing the demand for imported steel, two equations describing domestic and world steel production, an equation for world capacity, and two more equations describing domestic and foreign supply price.

The units of measurement can be chosen for convenience. The only limitation is that the prices of imported and domestic steel be in the same units. Hence, the equations are written so that several of the variables are indices with value 1 in the first period during which the model is projected. The variables measured as indices are world capacity (k), the domestic steel price (P), the U.S. price of steel-using commodities (py). The time trend (t) begins at 0 and increases 1 each quarter. The other variables have units determined by the equations.

(1) Import demand

$$m = \left[\frac{pm}{py}\right]^{-.345} Y$$

(2) Output of steel-using commodities in the U.S.

$$Y = e^{.006t}\left[1 + .054 \text{ sine } (.449\,(t+7))\right]$$

(3) World steel output

$$s = e^{.006t}\left[1 + .050 \text{ sine } (.449\,(t+7))\right]$$

(4) World steel-making capacity

$$k = e^{.006t}$$

(5) Prices of U.S. made steel and of output of steel-making commodities

$$P = py = e^{.026t}$$

(6) Import price

$$pm = Ae^{.026t}\left(\frac{s}{k}\right)^{1.84}.$$

Equation (1) states that import demand (m) depends on the price of imports relative to the price of output (pm/py) and on the level of output (Y) in the steel-using industries. The form of the equation can be derived from the assumption of a Constant Elasticity of Substitution production function for output (Y). That demand is proportional to output results from an assumption of constant returns to scale. The elasticity of substitution (.345) is from an earlier study [17].

Equations (2) and (3) describe trends and cycles in the output (Y) of steel-using commodities in the U.S. and in world steel output(s). Both are assumed to grow exponentially at .602 percent per quarter. This rate of growth is that of fixed, nonresidential investment in the U.S., taken as a proxy for the rate of growth of steel-using activity, domestic and foreign. The growth rate is calculated as a least squares trend in the log of investment from peak to peak over two cycles. The period covered is 1966-III to 1973-III.

In steel-using activity, domestic and foreign, cycles about the trend are assumed to take the form of a sine wave. The length of the wave is 14 quarters, since the two investment cycles discussed above cover 28 quarters.

The cycle in world steel output was assumed to coincide with the cycle in U.S. output of steel-using commodities, but its amplitude was allowed to differ. The amplitude of the U.S. cycle was estimated from the two cycles discussed earlier. The amplitude of the world cycle was estimated from the amplitude of cycles in world utilization over the period 1956 to 1976. Accordingly, the parameters determining the amplitude of the foreign and domestic cycles are different, .050 and .054 respectively.

Both cycles are shifted by 7 quarters by using t+7 as an argument in the sine functions of equations (2) and (3). This is done so that the cycle begins at the beginning of the trough, as the import price drops below its trend.

World steel-making capacity is assumed to be a simple exponential trend (equation 4). It is measured as an index, set equal to 1 in the first period of the simulation. Its rate of growth is the exponential trend assumed for world steel output.

U.S. prices of steel, and steel-making output, are both assumed to grow at 2.6 percent per quarter. This was calculated as the least squares trend in the logarithm of wholesale price index from the first quarter of 1972 to the second quarter of 1977. 1972 is when the recent inflation began to exceed 5 percent. Historically, the price of domestic steel has not been statistically related to demand fluctuations [17], so no influence of demand on price is built into the model.

The price of imported steel (equation 6 in the model) has the same rate of growth as the price of domestic steel. In addition, the import price shows a strong response to world market conditions, as measured by the ratio of world steel production to world capacity. The coefficient on this ratio 1.84 is taken from [17].

The remaining parameter (A) is adjusted so that the lower price of imports during troughs just compensates for the premium during booms. Since this price difference is what we want to measure, we will now discuss it in more detail.

Calculation of the Necessary Price Difference

The required lower prices of imports at the trough of the cycle must exactly balance expected higher import prices during booms. To derive this price, we estimate, for each quarter, the difference between the profits made by users of imported steel and the profits they would have made if they used domestic steel. This difference is the area under the demand curve between the import and domestic price, as discussed earlier. The present discounted value of these present and future profits is calculated at the beginning of the downturn in the cycle. To discount, we first deflate by the price of steel-using output, then use an inflation-corrected or real rate of return. The real interest rate used is 7 percent, a rate that is consistent with long term real returns on securities listed on the New York Stock Exchange [10].

For individual quarters, the gain or loss from using imports is the area to the left of the demand for imports and between the import price and the domestic price, illustrated earlier in figure 2 as area A+B. To make numerical estimates of this area, we integrate the demand for imports (equation 1) between the import and domestic price. This integral is:

(7) Extra Profits from Using Imports (In constant dollars)

$$\Pi = \frac{Y \cdot py^{.345}}{[1-.345]\, py} \quad [P^{1-.345} - pm^{1-.345}] .$$

The model is simulated to find the price of imports during cyclical troughs that will make Π sum to 0 over the cycle. The simulation shows that import prices must be about 9 percent below domestic prices, at the trough, to compensate for instability over the cycle.

THE COSTS TO IMPORTERS OF LONG LEAD TIMES

Several of the purchase conditions for imports suggest that higher inventories will be needed. These include longer waiting times, less certainty about waiting time, and larger order requirements. In this section we describe and apply a standard inventory model to estimate the costs of higher inventories resulting from longer average lead times. We did not attempt to make corresponding estimates for larger order requirements or uncertainty in waiting time.

One question that often arises in the discussion of costs associated with longer lead times is why lead times are important at all. After all, if the lead time for imports is longer, why not simply make plans earlier? The answer is that making plans ahead of time is costly. The primary cost is the risk that predictions on which the plans are based will be inaccurate and too much or too little will be ordered. This risk can plausibly be expected to be higher, the greater the distance into the future that must be projected.

Application of Inventory Model

The inventory model used is a standard one based on the tradeoffs between three costs of inventory strategy, the costs of making an order, the costs of storing the material to be inventoried (including carrying charges), and the costs of running out of the material (outage costs). If inventories are high, the storage costs will be high but the outage costs low; if inventories are low, storage costs will be low but outages will be more frequent and costly. The inventory model describes the way to minimize the expected sum of these costs by selecting an appropriate average level of inventory, size of order, and rule for when to reorder.

The model used is described in detail in [9]. The following parameters are required:

1. Expected lead time demand. This is the expected demand for the product during the time between the placing of an order and its receipt.
2. The variance of lead time demand.
3. Outage costs. The cost per unit of not having material when it is needed.
4. The form of lead time demand. We use a normal distribution. When substantial probability is associated with negative demand, the distribution is truncated at 0.

The model was applied in the following way. First, we used observed inventory levels held by steel purchasers to derive plausible values for other parameters in the model. This set of derived values was used to describe users of domestic steel. While any number of values for the parameters could be derived in this way, the results were insensitive to changes in the parameters. We present results for only one set.

Once a complete set of parameters for the model was derived, the parameter values were adjusted to represent the longer lead time for importers. Then, the inventory costs for import users were derived and compared with those for users of domestic steel. In making these calculations of extra cost, we assumed that a given purchaser over a specified period specializes in either domestic or imported steel for a particular kind of steel. He could, however, switch back and forth between imports and domestic steel during non-overlapping periods, or use different sources for different types of steel.

Results are reported in table 5 for a typical manufacturer using steel as an input (typical in the sense that he holds the average level of inventories). The manufacturer is assumed to use 1200 tons of a certain type of steel per year. (The absolute figure is unimportant. What matters is the relation to the variance of lead time demand.) From our interviews, we determined that lead time from domestic mills is about one month. Hence, expected lead time demand is 100 tons.

One parameter we need for the inventory model is the annual cost of holding one unit of steel in inventory, as a percentage of the purchase price of that unit.

TABLE 5

ANNUAL COST OF HOLDING ONE UNIT OF STEEL IN INVENTORY AS A FRACTION OF PURCHASE PRICE

Housing costs	6.8%
Inventory taxes and insurance	1.2%
Obsolescence	1.5%
Opportunity Cost of funds	7.0%
Total	16.5%

The source for the costs (other than costs of funds) is a report in Purchasing World, July 1972, p. 82. The opportunity cost of capital is the rate of return on the New York Stock Exchange corrected for inflation. We use the real return to account for appreciation on the price of inventory during storage.*

The cost of inventory is expressed as a fraction of the purchase price. This ignores any difference between the purchase price of imports and domestic production.

In normal times, the inventory of steel carried by users is 1.82 months. This is the ratio of average end-of-quarter inventories to average monthly steel consumption over the period 1970 to 1975.

To summarize, we start with the following magnitudes:

expected lead time demand	100 tons
cost of holding inventory of one unit for one year expressed as a fraction of purchase price	.165
observed average level of inventories	1.82 months

Table 6 shows estimates from the model of inventory cost per unit sales for a manufacturer using domestic steel.

As mentioned above, the overall results of this section are not greatly affected by reductions in the outage penalty so long as they are compensated by increases in the standard deviation of lead time demand sufficient to generate the observed level of inventories.

Table 6 shows estimates for a manufacturer using domestic steel, based on this complete set of inputs.

TABLE 6

OPTIMAL INVENTORY LEVEL, ORDER SIZE, AND INVENTORY COST FOR MANUFACTURERS USING DOMESTIC STEEL

optimal inventory level in months	1.82
optimal order size	103 tons
optimal annual inventory cost as a fraction of purchase price	3.2%

*The Purchasing World report uses 6.5% as the interest cost of holding inventory. It is not clear where this number comes from. It is clearly too low to represent nominal yields on corporate investment.

To estimate the corresponding costs for users of imported steel, we assume that the expected lead time increases from 1 to 3 months while the variance of lead time remains unchanged. Because lead time is longer, predictions must be made further into the future and the error in prediction will increase. Hence, the variance of lead time demand will grow, even though the variance of lead time itself does not.

The question now becomes, how much will this variance increase? To derive the increase in variance we assumed that the errors of prediction increased proportionately with the distance that must be predicted. Clearly this assumption cannot hold for predictions far into the future without implying massive errors. Yet the assumption is reasonable for a period of 1 to 3 months, which is the range of interest in this paper. The assumption about how errors depend on the distance to be forecast is important. We checked it by examining recent projections of total steel production in the U.S. made by a large econometric model. We found that the assumption predicted well relative to the assumption that the size of the error is uncorrelated with the length of time to be projected. (The proportional increase in error can also be generated by the assumption that future demand is a random walk.)

Using this assumption, we adjusted the parameters of inventory model to make them appropriate for describing import users. The expected lead time was lengthened to 3 months from 1 month, expected lead time demand was increased to 300 tons from 100 tons, and the standard deviation of lead time demand was increased to 248 tons from 50 tons. (For a detailed description of how the change in the standard deviation was derived, with emphasis on the role of the assumption about the error or prediction, see the appendix.)

Table 7 shows estimates for a manufacturer using imported steel.

TABLE 7

OPTIMAL INVENTORY LEVEL, ORDER SIZE, AND INVENTORY COST FOR A MANUFACTURER USING IMPORTED STEEL

optimal inventory level in months	7.47
optimal order size	228 tons
optimal annual inventory cost as a fraction of purchase price	11.9%

Since inventory costs are 11.9% of purchase price for import users, and 3.2% for domestic users, inventory costs associated with lead time differences can explain a price differential of about 8.7%.

CONCLUSION

Two negative characteristics of imports are their unstable price (which we have called insecurity of supply) and their long lead times. The estimated cost of using steel with these characteristics is substantial. Together, they require that the import price be about 17 percent below the domestic price if imports are to compete for the typical purchaser of steel.

These negative characteristics help explain why the import share has remained small, even when imports are priced well below the domestic price. Although some users will buy imports when the price differential is less than 17 percent, the typical user, who is now buying domestic steel, would not be tempted to shift.

REFERENCES

[1] Armington, Paul S., "A Theory of Demand for Products Distinguished by Place of Production," IMF Staff Papers, Vol. XVI No. 1 (March 1969), pp. 159-176.

[2] Burgess, David, "A Cost Minimization Approach to Import Demand Equations," Review of Economics and Statistics, May 1974, pp 225-234.

[3] Committee on Finance, U.S. Senate Staff Study, 90th Congress, 2nd Session, Steel Imports, 1968 (document 107), pp. 365-413.

[4] The Data Resources Review, Data Resources, Inc., Lexington, Mass., selected Monthly Issues, 1974-1976.

[5] "Drop in Imports Makes Steelmen Wonder if Days of Cheap Foreign Steel are Over," Wall Street Journal, 30 Dec 1975, p.22.

[6] "Feels Japan Will Honor Steel Price Commitments to U.S.," American Metal Market, 15 May 1973.

[7] "Foreign Steel Is No Bargain Now - But Domestic Often Isn't Either," American Metal Market - Steel Service Center Supplement, 11 May 1973.

[8] Goldberger, Arthur, Econometric Theory, Wiley, New York City, 1964, pp. 217-218.

[9] Hadley, G. and Whitin, T.M., Analysis of Inventory Systems, Prentice-Hall, Englewood Cliffs, N.J., 1963, pp. 159-175.

[10] Hayes, Samuel L., "Capital Commitments and the High Cost of Money, "Harvard Business Review, May-June 1977.

[11] Hearings Before the Committee on Ways and Means, U.S. House of Representatives, Foreign Trade and Tariff Proposals, Part 5, 18 Jun 1968, pp. 2088-2103.

[12] Ibid, pp. 2269-2272.

[13] Hogan, William T., Economic History of the Iron and Steel Industry in the United States, Part V, Lexington Books, 1971, p. 2037.

[14] Houthakker, H.S. and Magee, S. P.; "Income and Price Elasticities in World Trade," Review of Economics and Statistics, May 1969, pp. 111-125.

[15] "How Lloyd Konrad, A Purchasing Agent, Wheels for Good Deals," Wall Street Journal, 7 Oct 1975, p. 1.

[16] "Japanese Steel Prices on the Coast Pull Even With, May Fly Past U.S.," American Metal Market, 6 Jul 1973.

[17] Jondrow, James, et. al., Effects of Trade Restrictions on Imports of Steel, The Public Research Institute, Professional Paper 165, Nov 1976.

[18] Kravis, Irving B. and Lipsey, Robert E.; Price Competitiveness in World Trade, National Bureau of Economic Research, New York, 1971, p. 222.

[19] Kreinin, M., "Price Elasticities in International Trade, " Review of Economics and Statistics, Nov 1967, pp. 510-516.

[20] Magee, Stephen P., "A Theoretical and Empirical Examination of Supply and Demand Relationships in U.S. International Trade," Unpublished paper for Council of Economic Advisors, 1971.

[21] Marcus, Peter F., World Steel Supply Dynamics, 1975-81, Summary Report, Mitchel, Hutchins, Inc., 26 Feb 1976.

[22] Miller, Robert, "Price Stability, Market Control, and Imports in the Steel Industry," Journal of Marketing, Apr 1968, pp. 16-20.

[23] "MITI to Ask Mills for More Carbon Steel," American Metal Market, 12 Jun 1973.

[24] Mood, Alexander, Graybill, Franklin and Boes, Duane, Introduction to the Theory of Statistics, Third edition, McGraw-Hill, 1974, p. 181.

[25] Murray, Tracy and Ginman, Peter; "An Empirical Examination of the Traditional Aggregate Import Demand Model," The Review of Economics and Statistics, Feb 1976, pp. 75-80.

[26] "Price Freeze Apparently Will Do Little to Ease What Users See as Shortage," American Metal Market, 18 Jun 1973.

[27] Price, J.E. and Thornblade, J.B.; "U.S. Import Demand Equations Disaggregated by Country and Commodity," Southern Economic Journal, Jul 1972, pp. 46-57.

[28] Richardson, John David, "Some Issues in the Structural Determination of International Price Responsiveness," Paper presented at an International Colloquium on Quantitative Studies.

[29] Rosenberg, Lawrence, "The Impact of the Smithsonian and February 1973 Devaluations on Imports, a Case Study of Steel Imports," Unpublished paper, Department of the Treasury, 7 Aug 1973.

[30] Shipments data and real quarterly GNP are from Survey of Current Business.

[31] "Steel Imports Losing Force, But it's Not All to Good," American Metal Market, 1 May 1973.

[32] "Steel Lead-Times - Sheet, Strip Pricing Effects Pondered," American Metal Market, 14 May 1973.

[33] Stigler, George and Kindahl, James; The Behavior of Industrial Prices, National Bureau of Economic Research, 1970.

[34] A Study of Steel Prices, Executive Office of the President, Council on Wage and Price Stability, Staff Report, U.S. Government Printing Office, Jul 1975.

[35] U.S. International Trade Commission, Stainless Steel and Alloy Tool Steel, (U.S. ITC Publication 756), 16 Jan 1976, p. A-83.

[36] "U.S. Steel Cuts Prices to Tight Import Boom, Dismaying Other Mills," Wall Street Journal, 19 May 1968, p. 1.

[37] "Without Denying Boom, Steel Claims Seem Excessive," American Metal Market, 29 May 1973.

APPENDIX A

THE CALCULATION OF IMPORTER'S LOSS DUE TO LONGER NORMAL LEAD TIMES

APPENDIX A

THE CALCULATION OF IMPORTER'S LOSS DUE TO LONGER NORMAL LEAD TIMES

This appendix discusses two topics, the way in which the variance in lead time demand changes with expected lead time, and a derivative question, the way in which the accuracy of future prediction depends on the distance into the future that must be predicted.

The variance in lead time demand can be approximately decomposed into two components, one representing the variance in demand per unit time, and one representing the variance in lead time itself.

Assume a partitioning of the lead time into very fine equal units and define the following symbols:

y = the demand during one unit time period

t = the number of units into which lead time is divided

$x = \Sigma y$ *the demand during the entire time period*

$$\bar{y} = \frac{\Sigma y}{t} = \frac{x}{t} \quad .$$

It is convenient to represent the lead time demand x as $\bar{y} \cdot t$. The variance of x can be approximated by the variance of its first order Taylor expansion around the expected values of the two variables. For similar application of this technique see [8], [24].

Taylor expansion is:

$$\bar{y} = \bar{y}_o t_o + (\bar{y}-\bar{y}_o)t_o + (t-t_o)\bar{y}_o \tag{A-1}$$

where the subscript o denotes an expected value. Provided that t and $\bar{y}$ are uncorrelated, this variance is

$$v(x) = t_o^2 \, V(\bar{y}) + \bar{y}_o^2 \, v(t) \quad . \tag{A-2}$$

To evaluate this expression requires an assumption about how $v(\bar{y})$ depends on the average lead time. This, in turn, requires an assumption about how the accuracy of predicting y depends on the distance in advance that the prediction must be made. We will assume that the standard deviation of the error in prediction varies directly with the distance into the future of the time period to be predicted. This assumption is discussed in detail later in this appendix.

We assume too that the errors of prediction for non-overlapping future periods are independent. Under these assumptions, the variance of $\bar{y}$, conditional on t is

$$v(\bar{y}|t) = \frac{1}{t^2} v \sum_{i=1}^{t} y) = \frac{1}{t^2} \sum_{i=1}^{t} i^2 v_o = \frac{v_o}{t^2} \sum_{i=1}^{t} i^2 \tag{A-3}$$

where v_o is the variance of the lead time demand over the first small interval of time.

For large t, the summation is approximately equal to $t^3/3$, so that the variance of $\bar{y}$, given t is approximated by

$$v(\bar{y}|t) = \frac{v_o t}{3} \quad . \tag{A-4}$$

Assuming that $\bar{y}$ has the same mean regardless of t, the unconditional variance of $\bar{y}$ is just the average of the conditionals over t so that the unconditional variance is

$$v(\bar{y}) = \frac{v_o}{3} t_o \quad . \tag{A-5}$$

Substituting this in the earlier expression for the variance of lead time demand we obtain:

$$v(x) = \frac{t_o^3}{3} + y_o^2 \, v(t) \quad . \tag{A-6}$$

The increased expected lead time associated with imports increases the first term of the expression, but not the second. The first term changes by a factor of f^3, where f is the ratio of the new lead time to the old lead time. In our case, f is 3 and f^3 is 27. To adjust $v(x)$, we must subtract out the second term, multiply the first by 27, and then add back in the second. This requires an estimate of the second term, especially $v(t)$, the variance of lead time.

We approximate $v(t)$ by noting that for large domestic users, lead time is reliable within a week either way (according to one of our interviewees). If we assume a uniform density over this 2-week range, the variance is $v(t) = \frac{1}{48}$ month^2. Since y_o is 100 tons/month, the second term is

$$y_o^2 v(t) = 208 \text{ tons}^2 \quad .$$

Since the total variance in lead time demand used as an input to the inventory model is 2500 tons^2, the first term for users of domestic steel and for imported steel are:

2500 - 208 (domestic)
27(2500 - 208) (imported).

Adding back in the 208 for imported steel, we obtain a new variance of 62,092 and a new standard deviation of 249. This is to be compared with an original standard deviation of lead time demand of 50. In the process, the ratio of the standard deviation of lead time demand to its expectation has almost doubled.

We return now to the assumption that the accuracy of prediction varies proportionately with the distance to be predicted. This assumption was checked against the hypothesis that the accuracy is unchanged with the distance into the future that must be predicted. We looked at quarterly predictions made in late 1974 to early 1976 by the Data Resources Econometric Model [4]. The predictions were for the Federal Reserve Board Production Index of Iron and Steel Production.

Two competing models of error variance were compared:

1. $z = zp + \varepsilon$
2. $z = zp + T\varepsilon$

where z is actual quarterly steel production, zp is predicted, T is the number of quarters in advance for which the prediction is made, and ε is a random error with constant variance σ^2. The first model implies that the error variance does not grow with the distance of prediction T, and the second implies that it grows proportionately with T^2. Under the first assumption, the expected value of the absolute error is:

$$E(|\varepsilon|) = \alpha \quad .$$

Under the second assumption, this expected value is

$$E(|T\varepsilon|) = \beta T \quad .$$

To test these hypotheses we ran a regression of the form

$$\text{absolute error} = \alpha + \beta T \quad .$$

The observations were 15 errors of prediction of steel production for periods, 1, 2, and 3 quarters ahead. The results were as follows with t-values in parentheses:

$$\text{absolute error} = -.002 + .043T$$
$$(-.052) \quad (2.36)$$

$R^2 = .30$
$N = 15$.

These results provide some support for the hypothesis that accuracy of prediction varies, at least proportionately, with the distance of prediction and no support for the hypothesis that the error of prediction is unrelated to distance of prediction.

As mentioned in the text, the results involving the accuracy of prediction can also be derived using the hypothesis that demand is generated by a random walk. Suppose that demand in a single period follows the relation:

$$y_i = y_{i-1} + v_i \tag{A-8}$$

where v_i is a serially uncorrelated error term with constant variance v_o . Suppose the process begins at time $i=0$ and a prediction is made then. Demand at time i can then be written:

$$y_i = y_o + \sum_{j=0}^{i} v_j \quad . \tag{A-9}$$

The assumption of independent errors for successive y_i can not be made in this case, since errors for a later period include those for an earlier period.

For this reason, we do not assume independence of successive errors but calculate directly the average demand over the period, and evaluate its variance, given y_o . The average demand up to time t is

$$\begin{aligned} \bar{y} &= \frac{1}{t} \sum_{i=1}^{t} y_i = y_o + \frac{1}{t} \sum_{i=1}^{t} \sum_{j=1}^{i} v_j \\ &= y_o + \frac{1}{t} [tv_1 + (t-1)v_2 \ldots v_t] \quad . \end{aligned} \tag{A-10}$$

The variance of this average given y_o and t is

$$v(\bar{y}|t) = (\frac{1}{t})^2 [t^2 v_o + (t-1)^2 v_o \ldots v_o] \quad . \tag{A-11}$$

For large t , this is approximately $v(\bar{y}|t) = \frac{v_o t}{3}$. This duplicates the expression for the conditional variance of $\bar{y}$ derived earlier under the alternate assumption that errors for successive y's are independent and the standard deviation of the error in y grows proportionately with t . The rest of the derivation of the effect of lead time on the variance of lead time demand is unchanged.